Lipid and Moisture Content of Salmon Prey Organisms and Stomach Contents of Chum, Pink, and Sockeye Salmon in the Bering Sea

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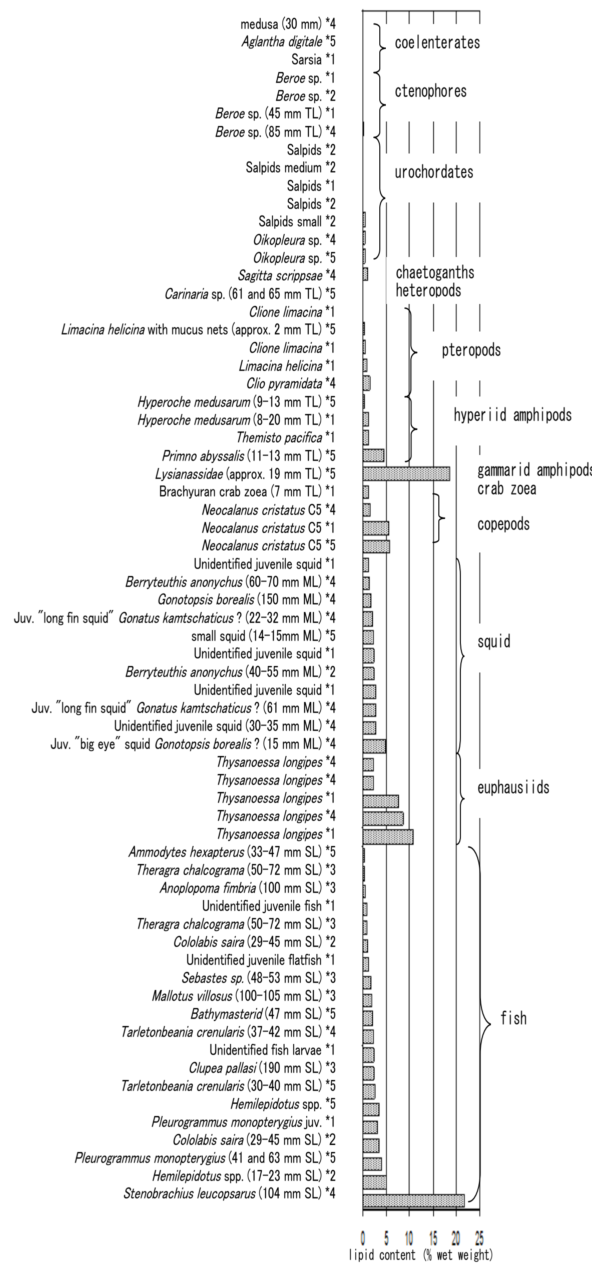
Keywords: Salmon prey, stomach contents, total lipid content, moisture

Lipids are a unique class of chemical compounds that all organisms require for survival. They are used primarily for energy storage, membrane structure, and hormones (Watanabe 1982). Recent results of studies investigating fish energy requirements have indicated that carnivorous fish, such as *Oncorhynchus*, have limited ability to utilize carbohydrates of high molecular weight as an energy source. Dietary lipids play an important role in providing energy, which spares dietary protein from being used an energy source. Although the lipid content of prey is the salmon's primary energy source, currently there is little information on the lipid content of salmon prey consumed in the marine environment (Higgs et al. 1995). To estimate the nutritional value of salmon prey, total lipid and moisture contents were determined from samples of salmon prey and salmon stomach contents collected during summer 2001–2004 and fall 2002 in the Bering Sea and North Pacific Ocean.

Sixty-six samples of salmon prey organisms were collected from plankton nets and fresh stomach contents of chum, pink, and sockeye salmon during the summer (June and July) 2001, 2002, 2003 and 2004 research cruises of the R/V *Wakatake maru* and fall (October) 2002 research cruise of the F/V *Northwest Explorer* (Table 1). In addition, unsorted representative samples of the stomach contents (bolus) were collected at the same time from chum, pink, and sockeye salmon caught during these cruises (Table 1). Unsorted samples of the stomach contents and identified salmon prey were collected on board the ship and then frozen at -30°C for further processing at the National Salmon Resources Center, Sapporo (NASREC). Samples were freeze-dried for determination of moisture content. Total lipid was extracted from the dried sample and measured using the method of Nomura et al. (2004).

Total lipid content of 66 samples of salmon prey varied between 0% and 21.8% of wet weight (Fig. 1). Coelenterates (< 0.1%), ctenophores (< 0.1% to 0.2%), pteropods (< 0.1% to 1.5%), heteropods (< 0.1%), and urochordates (< 0.1 to 0.5%) had lower total lipid content and less variation in their lipid levels than other prey taxa. In contrast, euphausiids (2.2–10.7%), copepods (1.3–5.7%), cephalopods (1.2–4.9%), and pisces (2.3–21.8%) contained relatively high lipid content.

Fig. 1. Total lipid content of salmon prey organisms collected in the central North Pacific Ocean and Bering Sea, 2001–2004. Prey organisms are ordered by increasing lipid content within taxonomic group. The * number refers to the group and sampling date shown in Table 1.



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Moisture content decreased with increased lipid content in the prey (Fig. 2). Prey organisms containing low lipid levels (ctenophores, coelenterates, pteropods, and urochordates) contained particularly high moisture content. In contrast, euphausiids and the myctophid, *Stenobrachius leucopsarus*, contained high lipid levels and low moisture content.

The average moisture content of stomach contents in chum, pink, and sockeye salmon was 83.2% (n = 158), 89.1% (n = 97), and 88.3%(n = 84), respectively (Table 2). Minimum and maximum values for moisture content of stomach contents in chum, pink, and sockeye salmon were 58.6–94.0%, 70.5–89.8%, and 68.9–89.6%, respectively. During 2001–2003, average total lipid contained in stomach contents of chum, pink, and sockeye salmon ranged from 2.5–3.8% (n = 158), 2.4–3.4% (n = 97), and 2.9–3.4% (n = 84), respectively.

We determined lipid and moisture content of salmon prey genera because the chemical composition of most prey species of Pacific salmon is unknown. Copepods are the only prey group where lipid storage has been relatively well studied. For these organisms, lipid levels can trigger diapause through variations in cholesterol and fatty-acid derived hormone levels, determine over-wintering depth, and have an important role in the population adaptations to the hydrological condition of their habitat (Campbell 2004; Irigoien 2004).

Based on our assessment, coelenterates, ctenophores, pteropods, heteropods, and urochordates do not appear to be a good source of energy for Pacific salmon. In contrast, euphausiids, copepods, cephalopods and fish appear to be good energy source for salmon. For example, rainbow trout, chinook and coho salmon need 15–20% lipid in dry diet for maximum growth efficiency (Higgs et al. 1995). The lipid content we observed in euphausiids, copepods, cephalopods, and fish (Fig. 1) is almost identical to the optimal lipid content for growth of *Oncorhynchus* species in the wild (Higgs et al. 1995). Our conclusion is preliminary until additional data are obtained and seasonal changes in lipid and moisture contents of salmon prey are determined. In addition, prey fatty-acid composition is an important component to assessing the nutritive value of prey. Although some prey may not be a particularly good energy source, they might be nutritious if they are a source of essential fatty-acids to the salmon. Therefore, we recommend continued monitoring of the lipid content and measuring fatty acid composition of salmon prey and stomach contents at sampling opportunities throughout the year.

Fig. 2. Relationship between total lipid content (%) and moisture (%) of salmon prey organisms.

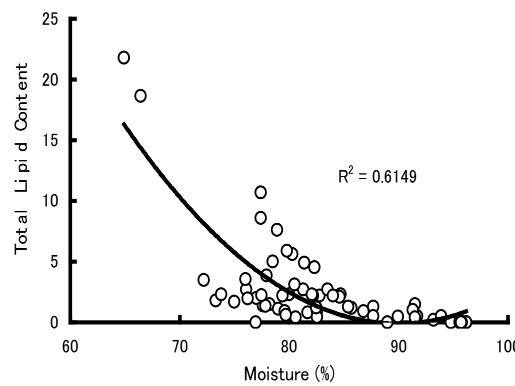

Table 1. Sampling date, season, research vessel, number of salmon prey samples, and number of salmon stomach samples collected in each sampling group.

Group	Year	Season	Date	Research Vessel	Salmon Prey Samples (n)	Salmon Stomach Samples (n)
1	2001	Summer	July 29–June 13	*Wakatake maru*	18	21
2	2002	Summer	June 28–July 13	*Wakatake maru*	9	141
3	2002	Fall	Sept. 8–Oct. 6	*Northwest Explorer*	6	98
4	2003	Summer	June 26–July 10	*Wakatake maru*	17	178
5	2004	Summer	June 26-July 9	*Wakatake maru*	16	0

Table 2. Maximum, minimum, and average of total lipid content (TL) as a percentage of wet matter in stomach contents of chum, pink, and sockeye salmon collected in the North Pacific Ocean and the Bering Sea from 2001–2003.

Year	Season	Species	n	TL (%)		
				Min.	Max.	Average (S.D.)
2001	Summer	Chum	21	0.4	9.1	2.5(2.0)
2002	Summer	Sockeye	27	1.2	11.8	3.8(2.1)
		Chum	99	0.3	10.0	3.1(1.5)
		Pink	15	0.7	12.6	2.9(2.8)
2002	Fall	Sockeye	26	0	9.5	2.5(2.0)
		Chum	72	0	13.8	3.4(3.6)
2003	Summer	Sockeye	31	1.2	7.7	3.1(1.4)
		Chum	65	0.6	6.3	2.4(1.2)
		Pink	82	0.3	15.9	3.4(2.4)

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